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Comparing Assistantship vs. Course-Based Undergraduate Research Opportunities

Leslie Potter

Iowa State University, potter@iastate.edu

Devna F. Popejoy-Sheriff

Iowa State University, devna@iastate.edu

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Keywords

Undergraduate research assistantship, course-based undergraduate research experience, REU, CURE, cost comparison

Disciplines

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Comments

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Comparing Assistantship vs. Course-Based Undergraduate Research Opportunities

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L. Potter and D. Popejoy-Sheriff
Iowa State University
Ames, Iowa 50011, USA

Abstract

Data from across STEM disciplines and over decades show that undergraduate research experiences are a positive significant factor for students who decide to continue with graduate school. We investigate if the same result holds true specifically for undergraduate industrial engineering students at a large, Midwestern university where recent and rapid increases in enrollment make providing one-on-one mentor relationships between faculty and students more challenging. A departmental Undergraduate Research Assistantship (URA) program was established in 2013. With the program now instilled, an assessment of impact to student perceptions and actual student career decisions (continuation to graduate school or not) is prudent, as resources for future increases in URA activities are considered. Increasing the number of available URA research positions is one option, but is limited by faculty time/availability constraints. A second, higher-capacity option would be to establish a CURE: a course-based undergraduate research experience. This decision requires a cost/benefit analysis – do more industrial engineering students who have undergraduate experiences continue to and succeed in graduate school than those who don't? We examine the data through the established SURE-III survey, and offer lessons learned and recommendations to industrial engineering departments that are considering establishing a URA program or CURE.

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1. Introduction

Across decades and STEM disciplines, data show that students benefit from undergraduate research (UR) experiences in many ways. Undergraduate research encompasses scholarship and creative activity, and is “a high-impact educational practice that has the ability to capture student interest and create enthusiasm for and engagement in an area of study” [1]. The Council on Undergraduate Research (CUR) defines undergraduate research as “an inquiry or investigation conducted by an undergraduate student that makes an original intellectual or creative contribution to the discipline” [2]. Multiple authors, institutions, and organizations cite this same definition [3, 4, 5].

CUR was founded in 1978 by chemists from liberal arts colleges, and since its inception, more than 650 colleges and universities have joined the organization, representing “all disciplines” [2]. A quick web search on “undergraduate research” returns countless programs, papers, proceedings, and online articles that span the science, technology, engineering and mathematics (STEM) spectrum, from chemistry to psychology, physics to math, and across the engineering disciplines. However, very little about undergraduate research with respect to industrial engineering education has been published. In the conference proceedings of the Institute of Industrial and Systems Engineers, a search on the same phrase across the entire available online database (2009-2015) generates four returns, only one of which considers the impact of undergraduate research on a student's decision to go to graduate school, and for this submission there was no paper (presentation only).

1.1 Support for Undergraduate Research

The 2013 U.S. Census Bureau survey shows that for Americans 25 years of age and over, 14.4% have a B.S.-only degree, and 11.7% hold a Masters, Professional, or Ph.D. [6]. Harris et al. note that research experiences may increase

the interest of students to pursue scientific studies [7]. The National Science Foundation (NSF) states on its Research Experiences for Undergraduates (REU) solicitation site that “research experience is one of the most effective avenues for attracting students to and retaining them in science and engineering...” [8]. CUR’s stated benefits of UR, include but are not limited to, increased retention and increased enrollment in graduate education [2].

According to the non-profit research institute, SRI International, analysis of data from almost 15,000 respondents to four online surveys (NSF-program participant initial and follow-up surveys of undergraduates, graduate students, post-doctoral candidates, and faculty; a nationally representative survey of B.S. graduates in STEM; and a nationally representative survey of B.S. graduates in social, behavioral or economic science), indicated that undergraduate research increases the likelihood of a student obtaining a doctorate degree [4]. Numerous citations from the growing body of research which documents student benefits gained from UR are noted by Auchincloss et al., spanning publications from 1990 to 2011 [9]. In 2004, Lopatto showed that over 83% of 1135 science undergraduate research student respondents from 41 institutions to a survey about the benefits of UR either began or continued to plan for further education in science [10]. In 2009 Lopatto presented survey data indicating that approximately 90% of REU students did not change their plans because of an REU experience [3]. Lopatto noted that some research findings have shown no increased interest in graduate studies as a result of UR, but others show significant increases in interest [3].

1.2 Types of Undergraduate Research

There are several undergraduate research methods commonly employed by academic institutions. Summer programs (often called REUs) and undergraduate research assistantships (URAs) held during the academic year are both similar to internships where students work individually and independently with a faculty mentor and/or graduate student. In course-based research experiences (CUREs), students do novel research within a course, working with other students. Funding for these programs can include external grants from organizations like NSF or industry, or can be internally funded by departments or colleges.

As defined by Bell et al., course-based undergraduate research experiences contribute to scientific identity, self-efficacy, and values alignment through three principles: discovery, iteration, and student ownership [11]. Auchincloss et al. define CUREs as involving the use of scientific practices, discovery, broadly relevant or important work, collaboration, and iteration within a course, and note that “it is the integration of all five dimensions that makes a learning experience a CURE” [9]. There are many shared outcomes between REUs and CUREs: increased critical thinking, problem solving, networking, communication skills, confidence, and a better understanding about the culture of research and graduate school [7]. Critically, both CUREs and REUs meet the definition of undergraduate research, where traditional lab experiences do not [9]. Overath et al. specifically address CUREs as a means to increase the number of students who consider STEM and research careers [12].

There are also differences: in a CURE, there is more inherent teamwork, while an REU is a more independent research experience [7]. One important difference is how many students can participate. Greater numbers of students can be introduced to research through CUREs than through traditional undergraduate research internship programs [7]. CUREs can be successfully integrated into introductory-level courses (11, 12, 13); consequently, they can potentially influence more students’ career choices sooner than REUs, which often occur later in an undergraduate’s academic career [9]. Rowlett et al. note that because pursuing research is intellectually beneficial to all students, undergraduate research opportunities should be accessible to as many students “as is practical” [1].

As with any new program, implementing undergraduate research in any form requires resources in terms of both time and money. A lack of resources can restrict or prohibit the implementation of effective pedagogies, even when expected outcomes are beneficial. Paul notes that pressures to reduce costs and increase faculty productivity detract from implementing UR programs, even when they are widely recognized as a “high-impact learning practice” [14]. Building any successful undergraduate research program requires appropriate financial and human resources, including real costs for materials and personnel [1]. Harris et al. identify both time and funding as two of the many obstacles to successful CURE implementation [9].

1.3 Background of IMSE Department’s Undergraduate Research Program at Iowa State University

The Industrial and Manufacturing Systems Engineering (IMSE) department at Iowa State University in Ames, Iowa, as part of its land grant mission and strategic goals, aims to ensure that students receive an exceptional education [15]. Specifically, this will be accomplished through “practical, global, and leadership experiences that shape the well-

rounded citizens and informed critical thinkers needed in the 21st century” [15]. Part of those experiences can, and we maintain should, include an undergraduate research experience.

ISU’s IMSE focus areas include Operations Research and Analytics, Manufacturing, Human Factors, Systems Engineering and Engineering Management, and Enterprise Computing [16]. Undergraduate and graduate degrees are conferred; in 2015, there were 484 full-time undergraduate students and 84 full-time graduate students enrolled, taught by 22.5 full-time equivalent faculty [17]. Critically important, the IMSE Department has had extraordinary growth over the past five years, with full-time undergraduate enrollment increasing 92.8% compared to university growth of 23.4% during the same timeframe. IMSE undergraduate student, faculty, and graduate student populations for 2011-2015 (the latest year published by the American Society for Engineering Education, or ASEE) are shown in Figure 1.

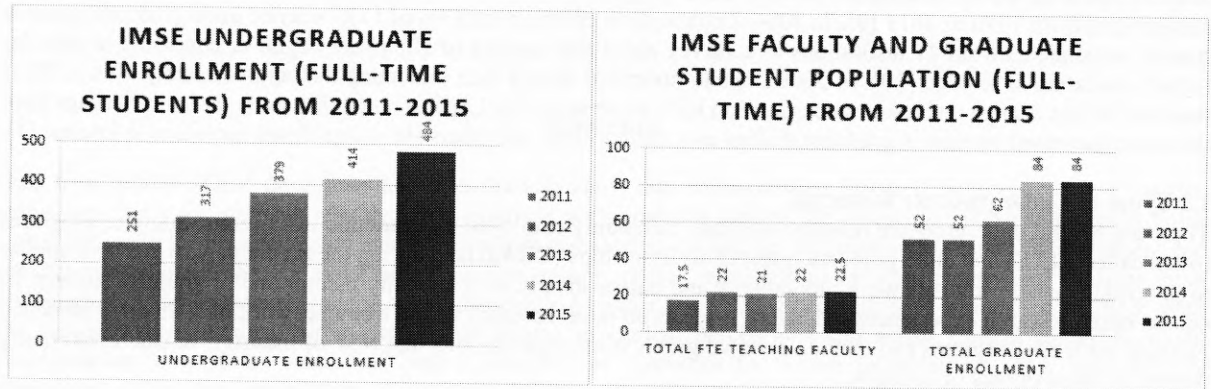


Figure 1: IMSE Student and Faculty Populations for Years 2011-2015

In 2013, the IMSE Department implemented an Undergraduate Research Assistantship (internship type, henceforth referred to as URA) program. Previously, faculty had independently employed URA students through their own funding, but the department had never funded students nor had a formal program for matching faculty and student interests. In the spring 2013 semester, eleven students were matched with faculty mentors and paid \$10/hour for up to 10 hrs/week for 10 weeks (a maximum of \$1000/student/semester). The program was administered by two co-chairs, including a departmental faculty member and a staff member. At the semester’s end, students presented their research response from all parties involved was positive, and with that, the program was instilled. Over the subsequent seven semesters, the program co-chairs have, with the input of student and faculty participants, continuously improved the program logistics and delivery. The number of students supported by the department during the program’s eight semesters has ranged from 9 to 16. A total of 110 semester positions filled by 67 individual students have been funded by the department since 2013.

The ISU College of Engineering Career Services posts self-reported graduate placements each year. From 2011-2015, the number of IMSE students self-reporting plans to attend graduate school has increased significantly, from 2 to 19, as shown in Table 1 (we note that in 2015, 92.8% of all graduates responded to the voluntary survey) [18]. The IMSE Department advisor knows how many students from the 2013-2016 URA cohort continue to graduate school. As of the fall 2016 semester, 15 of the 67 students are actively in or graduated from graduate school, with another 3 students applying for the fall 2017 semester, totaling 26.9% of all URA department-funded participants thus far.

Table 1: IMSE Graduate Self-Reported Plans to Continue to Graduate School

Year	2011	2012	2013	2014	2015
IMSE Graduates Self-Reporting Going to Graduate School	2	4	13	14	19

1.4 Decision point: keep the URA model and/or implement a CURE?

In this analysis, “benefit” is defined as any IE undergraduate student who decides to continue to graduate school. Increasing the benefit (i.e., increasing the number of students who go on to graduate school) is both desirable and,

arguably, professionally imperative. Since research shows that exposure to an undergraduate research experience increases the likelihood of a student choosing to pursue graduate education, then the question is how best to increase this benefit? Given the overwhelming success of our current URA model, but recognizing the need to increase exposure to more students, it is prudent to do a cost/benefit analysis. Assuming the benefit is approximately the same outcome for both the URA and the CURE models (i.e., approximately the same proportion of students who experience either will consider graduate school), the comparison is cost/student.

2. Methods

We compare the percentage of IMSE URA program students who continue to graduate school with the general population (age 25 and over) of persons with graduate degrees (25.4% vs. 11.7% [6]). We also compare it with the population of self-reporting graduates to the ISU College of Engineering Career Services vs. the number of graduating seniors enrolled in ISU's IMSE Department in 2011, who self-reported plans to go to graduate school (25.4% vs. 2/61 [18, 17], or 3.3% degrees awarded). We note that because the Career Services data is voluntarily reported, it is also likely under-reported, but that in 2015, 92.8% of all graduating IE students did report (we do not know how many graduates self-reported in 2011).

While the numbers appear very encouraging, they don't tell us what our graduates think of their URA experiences. For that reason, we engaged Dr. David Lopatto, Grinnell College, to participate in his SURE III survey, which had approval from the Grinnell College Institutional Review Board (IRB). The SURE III survey is meant for students who participate in an internship-like (REU, URA) undergraduate research experience. It is meant to be completed immediately after the experience concludes. In December 2016, 23 of our participating URA students (most department-funded, but some faculty-funded), voluntarily responded to Dr. Lopatto's survey questions about graduate plans. Aggregate data shows that from beginning to end of the students' projects, the number of students who had not considered post-undergraduate education decreased from 6 to 1, with an increase of 4 students (from 1 to 5) responding positively to now planning on pursuing a Ph.D. and an increase of 1 student (from 2 to 3) responding positively to now planning on pursuing a Master's degree. The results, which also show all national 2016 SURE III survey respondents as well as the subset of those who indicate their field of study as engineering, are shown in Table 2.

Table 2: SURE III Survey results after fall 2016 IMSE URA students responded

Survey question about post-undergraduate plans	IMSE Students, Fall 2016		All Engineering Students		All Students	
	Before Project	After Project	Before Project	After Project	Before Project	After Project
I had not considered post-undergraduate education	6	1	34	7	238	84
I planned not to pursue education	7	7	30	24	162	121
Masters in science field	7	7	113	115	598	607
Ph.D. in science field	1	5	81	100	1166	1349
Masters in nonscience field	2	3	5	2	76	78
Ph.D. in nonscience field	0	0	2	4	54	73
Medical degree	0	0	28	27	854	747
Law or professional degree	0	0	1	1	67	66
TOTAL STUDENT RESPONDENTS	23	23	294	280	3215	3125

Given that a benefit exists, and that current research indicates that a CURE experience can be just as beneficial as a URA experience, the question to be addressed is what is the investment (i.e., cost) per student for an undergraduate research experience? We identified the following as tangible costs for "producing" an undergraduate research experience: faculty cost (based on invested time), teaching and/or research assistant cost (based on invested time), administrator costs to support the program, direct supply costs, and student participant salaries. Over a 10-week URA program, we estimate that a faculty member spends approximately 20 hours either directly working with a URA student, mentoring a graduate student on how to work with a URA student, or attending required program meetings/presentations. We estimate faculty salary cost at \$80/hour. Note, we do not consider tradeoffs that faculty must make regarding time commitments to URA vs. other activities, nor do we consider these for the CURE model, either. We estimate that approximately 20 teaching and/or research assistant (TA/RA) hours are required per URA student, at a salary cost of \$15/hour. We estimate 3 hours of administrative time are invested per URA student at a salary cost of \$35/hour. This includes the time required by the program administrators along with that of a communications specialist, payroll, etc. Supply costs for URA students include program materials, food, and individual poster printing costs. These are estimated at \$100/participant. Last but not least, student participants in the

URA program are paid \$10/hour for up to 10 hours/week, for 10 weeks/semester, totaling a maximum of \$1000. The total cost per URA student is approximately \$3105/semester, summarized in Table 3.

For a CURE program, we assume that a faculty member will have 80 students/section, with TA/RA assistance. If a course-based research activity lasts for eight weeks and requires a total of 24 faculty contact hours, and if we assume that those contact hours require 100 hours of preparation time, then 124 faculty hours/80 students = 1.55 hours/student, or \$124/student. Likewise, if a CURE model requires 10 hours/week for 8 weeks from a TA/RA, this is 1 hour/student, or \$15/student for TA/RA time. Because the CURE happens within a course, there is no program to be administered, so administration time is zero. We estimate supply cost/student at \$35; this includes printing one poster for each group of four students, as well as laboratory supplies that support the research activities. There is no URA salary, and in fact, we do not include any extra income that might be received by the department as part of laboratory fees.

3. Results and Discussion

With eight semesters of URA program experience, we have learned how best to keep experiences positive and productive. Three key recommendations are made for URA programs: 1) Both students and faculty need to be clear about expectations. What can a student expect to do and accomplish in ten weeks? 2) Meetings should be to the point and create a sense of community. Oral meeting content is kept to 15 minutes, with more time for faculty and students to socialize and plan schedules. 3) Students must be informed that they must “manage faculty.” Undergraduate students need permission to speak “as researchers.” Students must be encouraged to be proactive and tenacious about meeting with faculty, and to ask questions when they don’t understand.

Within a mature and streamlined URA program, the cost comparison for the benefit of one student to have an undergraduate research experience is significant, as seen in Table 3. It is approximately 17 times more expensive per student to provide internship-like experiences through a URA than within a CURE. External funding could be pursued to increase the number of URA experiences that could be offered, but this also has a cost in terms of faculty time, and there is a practical limit to how many URA students can be effectively mentored by any faculty member in addition to other expected work obligations during a semester. Increasing the number of faculty is another option for increasing the number of URA students who can be mentored. However, this also has a practical limit. To significantly increase the number of students who experience undergraduate research in our department, with the anticipated departmental benefit being an increased number of students who continue to graduate school, a CURE pedagogy should be tried.

Table 3: Cost comparison of producing one URA experience vs. one CURE experience

	URA	CURE
Faculty cost	\$ 1,600.00	\$ 124.00
TA/RA cost	\$ 300.00	\$ 15.00
Administrator cost	\$ 105.00	-
Supply cost	\$ 100.00	\$ 35.00
URA Salary	\$ 1,000.00	-
TOTAL	\$ 3,105.00	\$ 174.00

To implement a CURE within our department, we will use “how to” resources available, such as “Developing and Sustaining a Research-Supportive Curriculum: A Compendium of Successful Practices,” edited by Karukstis and Elgren. This and other resources offered through CUR will reduce our learning curve; we will use others’ experience and advice to efficiently implement a CURE in our department.

4. Conclusions

Undergraduate research experiences should be considered as a means of increasing the number of students continuing to graduate school. Our URA program, established in 2013 and which employs the internship-type model of experience, has been successful. Based on third-party SURE III survey results of our own URA student participants, we saw a measurable increase in the number of students who considered graduate school after a URA experience. However, with unprecedented enrollment increases over the past four years, the percentage of students who can experience a URA opportunity is quickly shrinking, and it is imperative that we consider other resource-efficient alternatives, either in place of or in addition to our existing program.

The CURE pedagogy isn't inherently better than a URA program. CUREs are complementary to REUs [7, 9]. While CUREs may offer more teamwork [7] and collaboration opportunities, they may also be more limited in terms of student exposure, reducing the likelihood that students will develop a scientific identity [9]. Because CUREs have a significantly higher student to mentor ratio, they might not allow students to develop as close of collegial relationships with their mentors [9]. However, the literature indicates that similar results in terms of students choosing to consider graduate school can be accomplished through CUREs [12].

A cost comparison per student between CUREs (\$174/student) and URAs (\$3105/student) was completed. Given the relative similarity in expected benefit between CUREs and URAs, and the significant difference in investment per student between CUREs and URAs, CUREs are certainly worth trying to increase undergraduate research exposure in a quickly growing industrial engineering department. We plan to implement our first CURE in the 2017-2018 academic year, in a required sophomore level course and then make a full comparison between URA and CURE effectiveness.

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